333/909 AU 252 49103

995

GB 002235828 A,
MAR 1991

(12) UK Patent Application (19) GB (11) 2 235 828 (13) A

(43) Date of A publication 13.03.1991

(21) Application No 8919813.9

(22) Date of filing 01.09.1989

(71) Applicant
GEC-Marconi Limited

(Incorporated in the United Kingdom)

The Grove, Warren Lane, Stanmore, Middlesex, HA7 4LY, United Kingdom

(72) Inventor
Brian Frederick Nicholson

(74) Agent and/or Address for Service
G Cockayne
GEC Patent Department, GEC-Marconi Research Centre, West Hanningfield Road, Great Baddow, Chelmsford, Essex, CM2 8HN, United Kingdom

(51) INT CL[5]
H01P 1/207

(52) UK CL (Edition K)
H1W WBA W1 W3AX W9

(56) Documents cited
SU 0671672 A

(58) Field of search
UK CL (Edition J) H1W WBA WBX
INT CL[4] H01P
WPI

(54) **Superconductive waveguide filter**

(57) Filter apparatus comprises at least one superconductive element 13 within a waveguide 12 and forming at least part of a resonant structure. This gives a low loss filter with a uniform passband. A plurality of superconductive elements 13-16 may be provided and by controlling the state of the elements so that they are either superconductive or non-superconductive it is possible to control the filter characteristics after assembly or during operation of the filter.

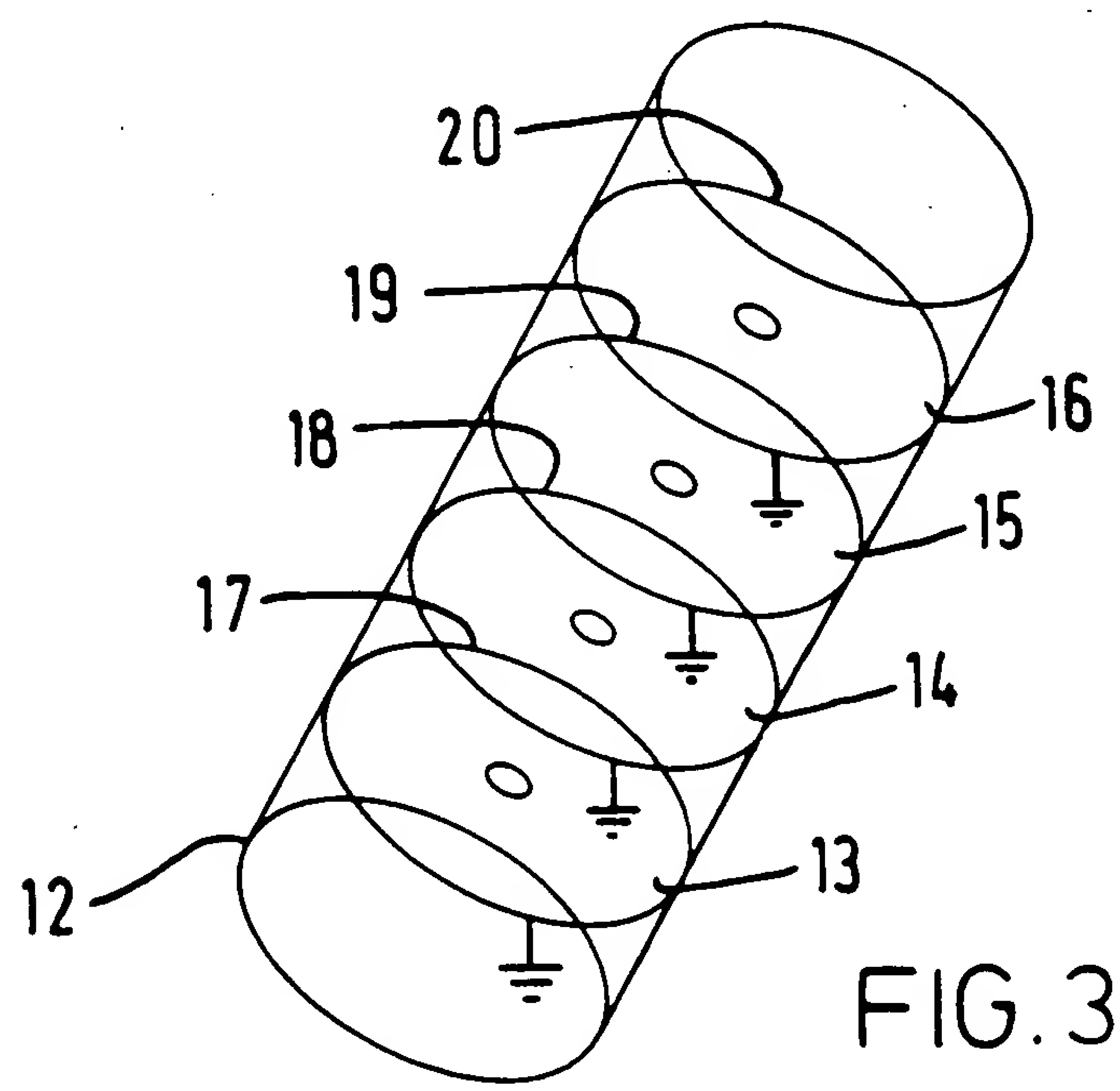


FIG. 3A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy

GB 2 235 828 A

FIG.1A

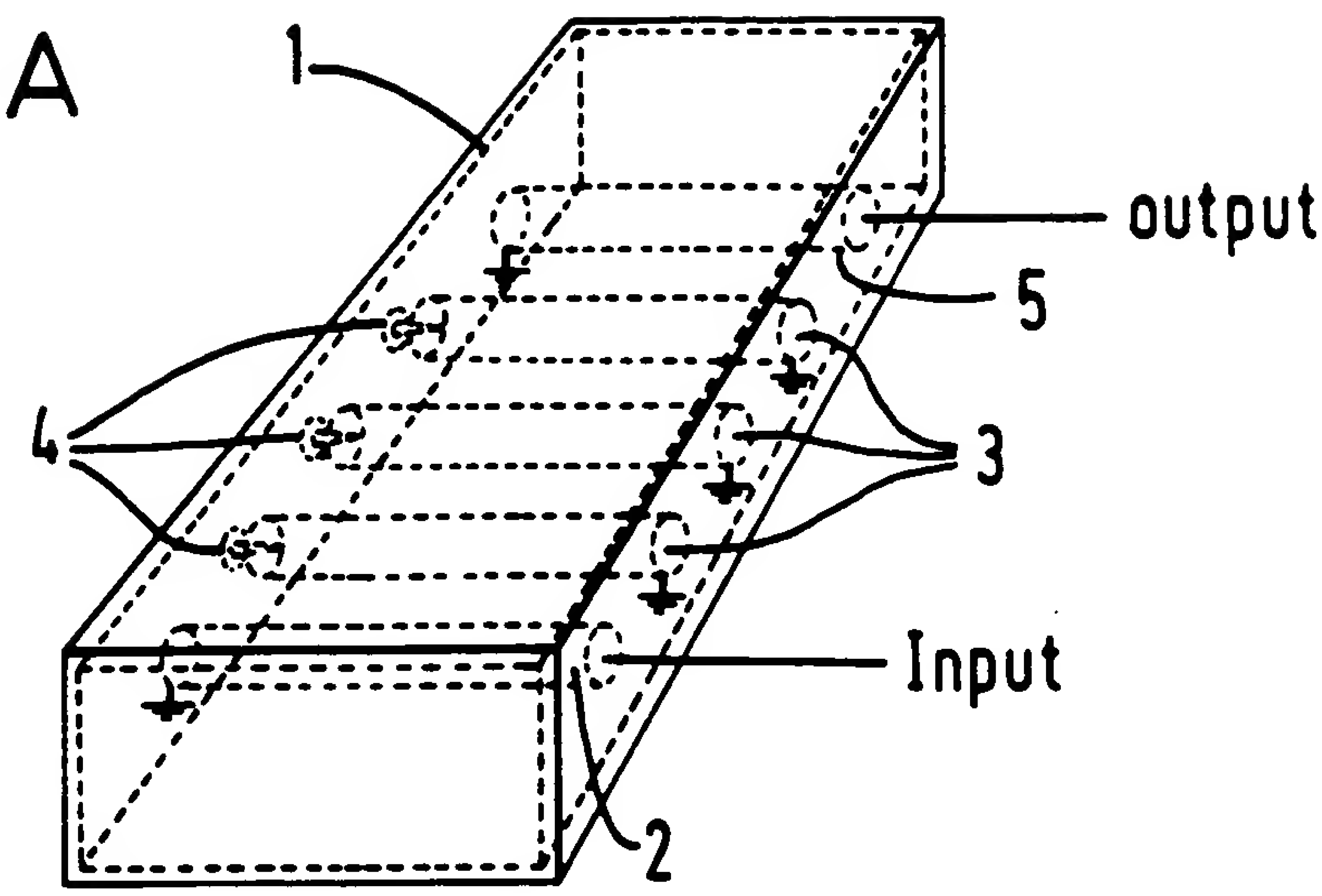
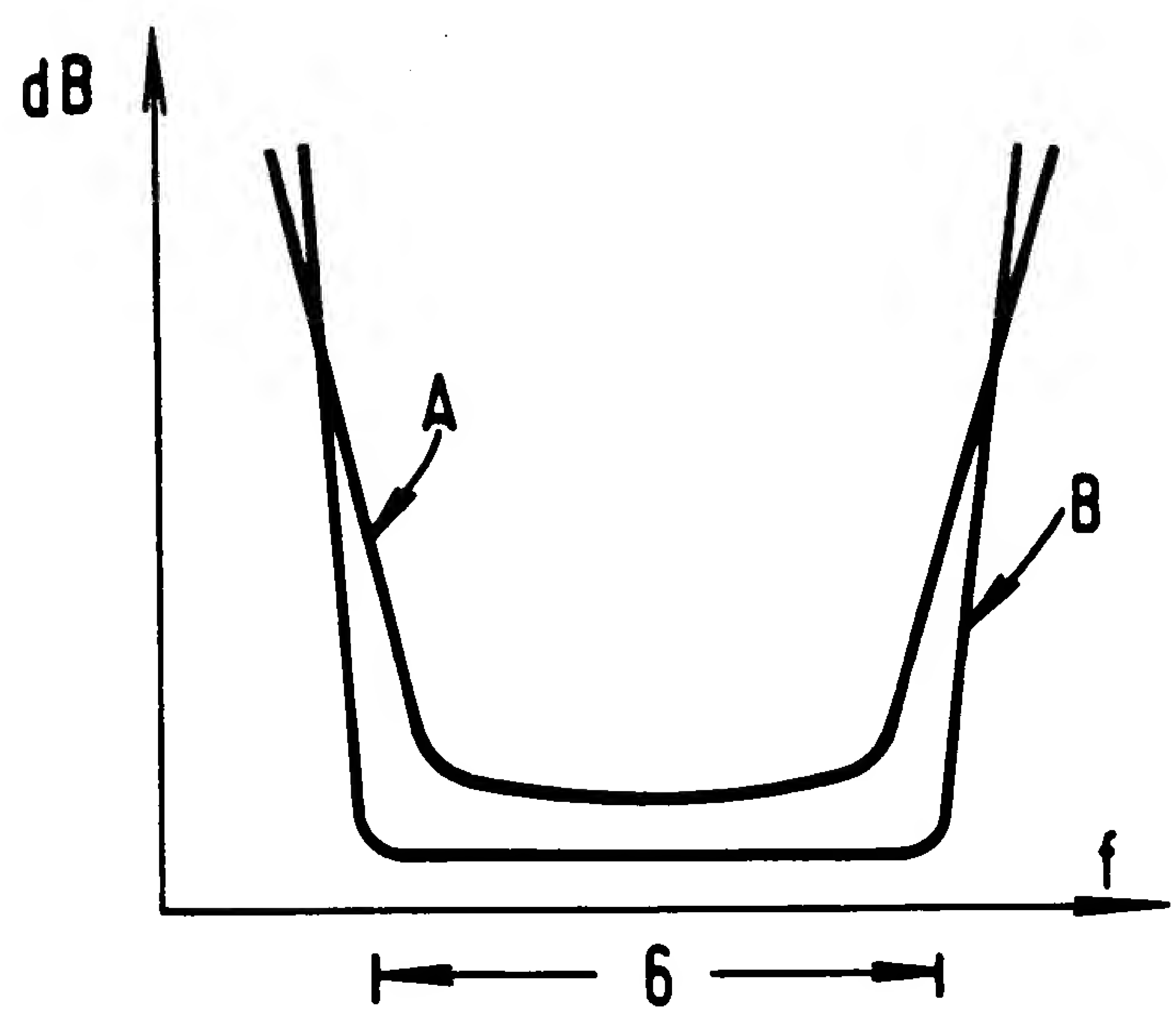


FIG.1B



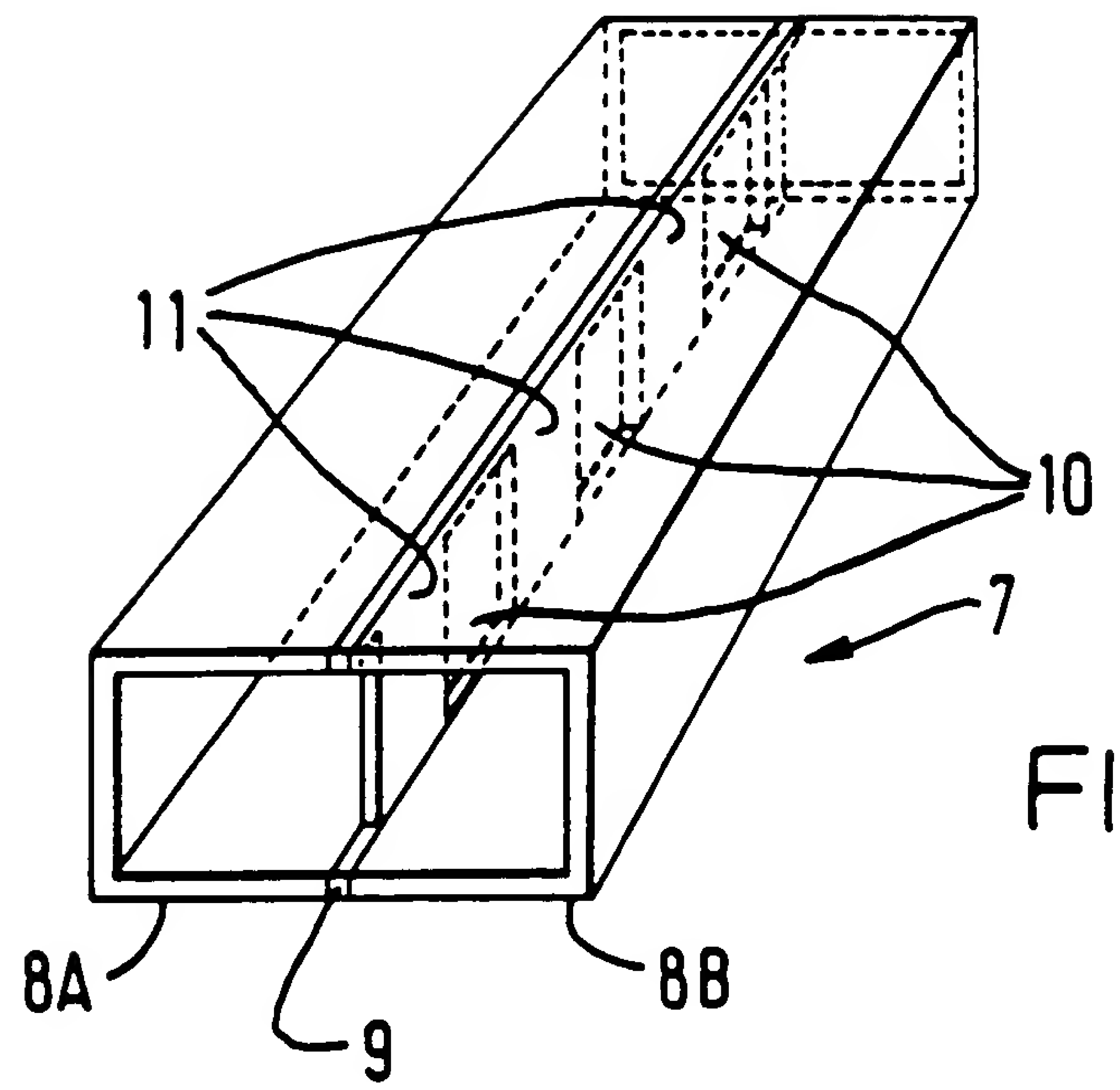
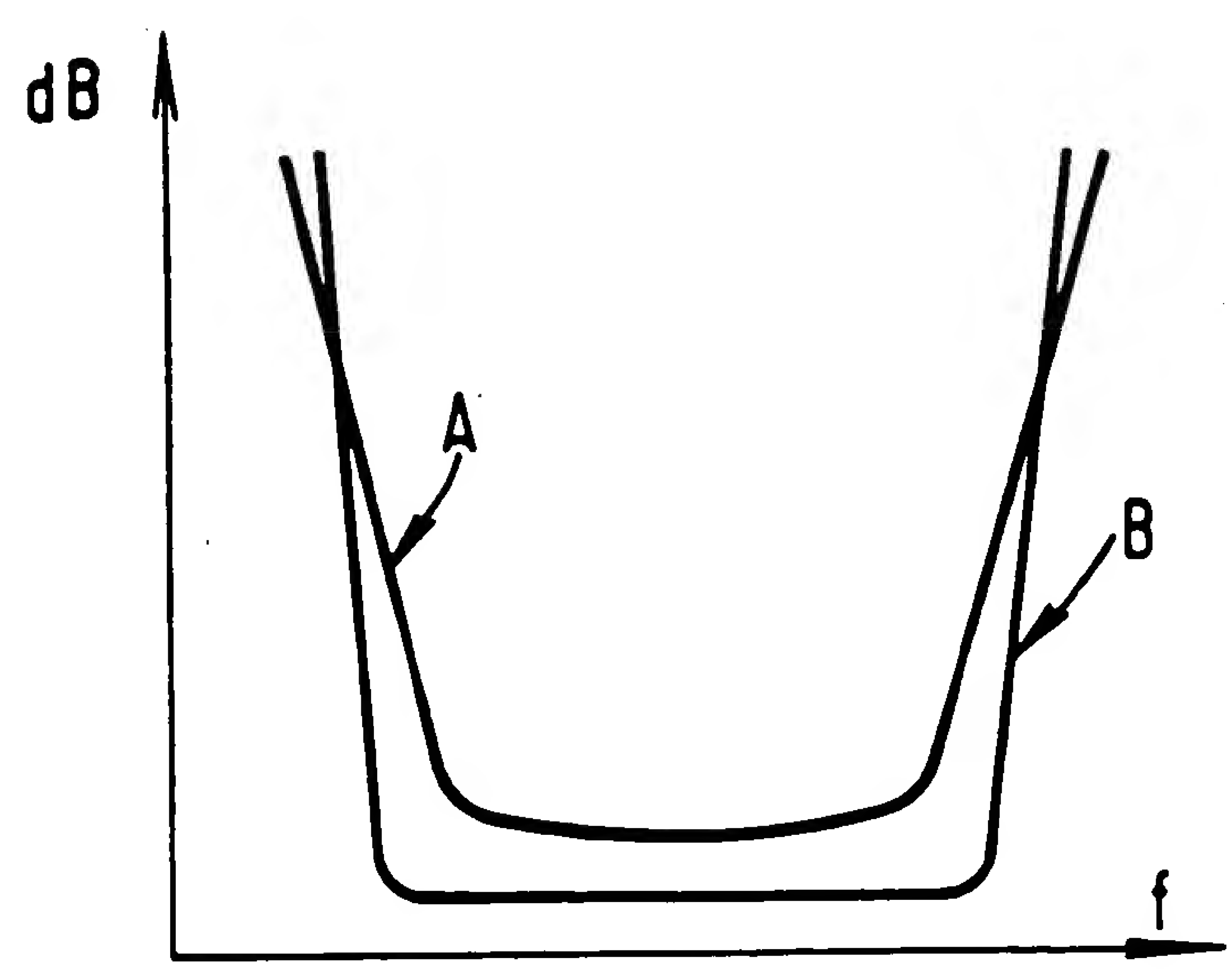


FIG. 2A

FIG. 2B



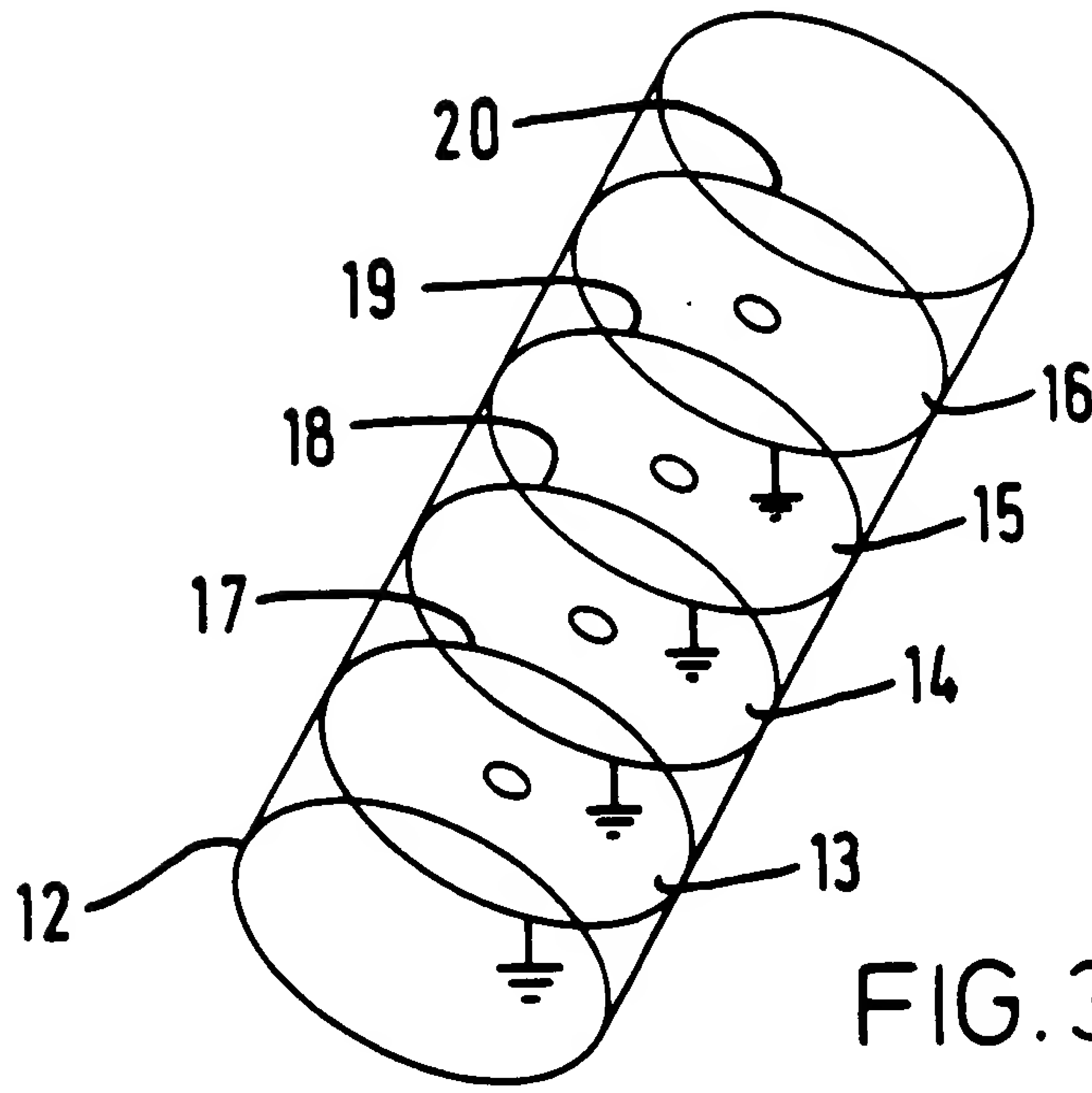


FIG.3A

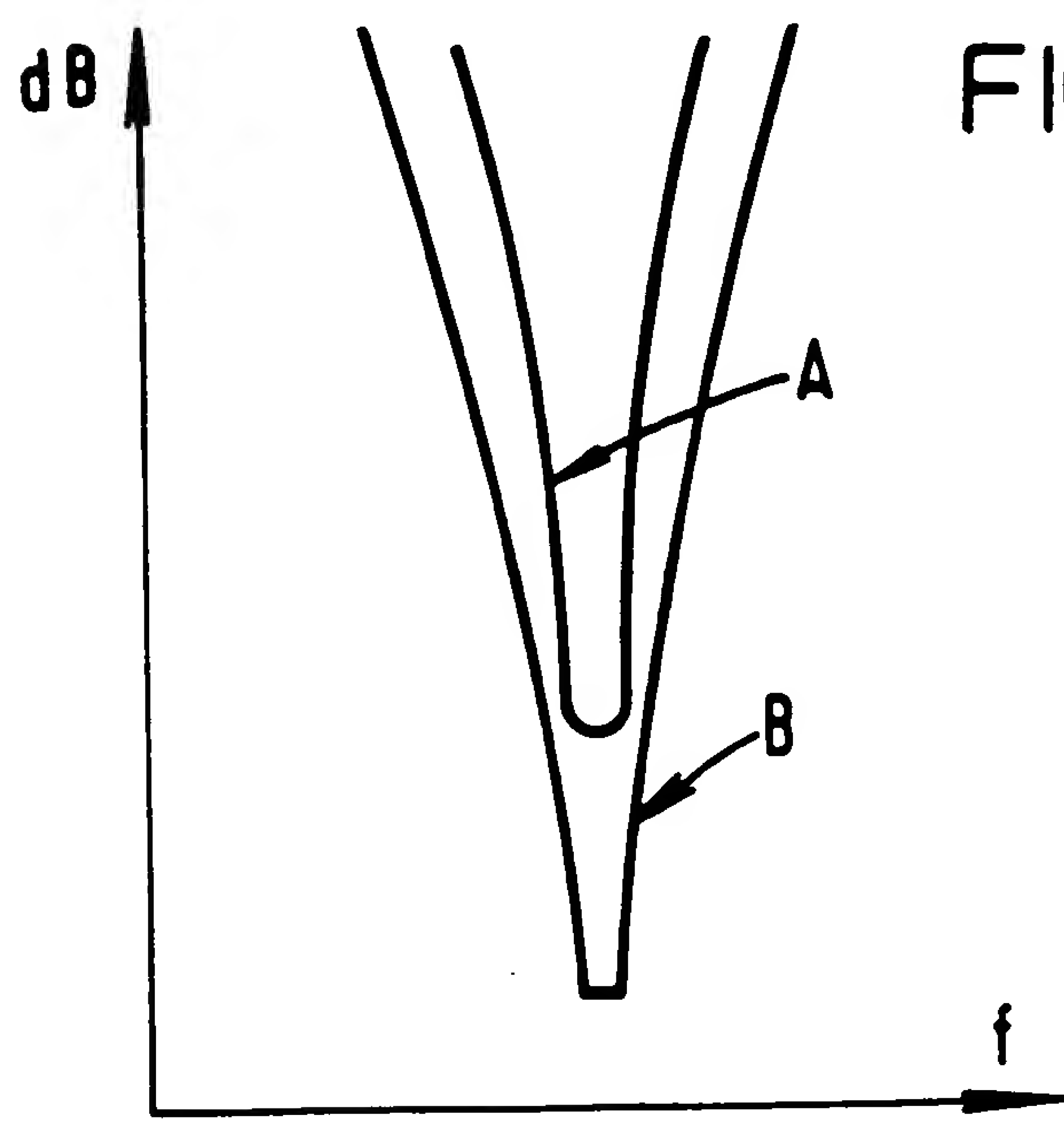


FIG.3B

SUPERCONDUCTIVE FILTER

This invention relates to waveguide filters for electromagnetic radiation and more particularly to waveguide filters which make use of the phenomenon of superconductivity.

There are a number of different filter types for use in waveguide applications, falling mainly into the four categories, low-pass, band-pass, band stop and high-pass filters, the type most frequently encountered being the band-pass filter. This is often a tuned cavity device so configured that it is only possible for frequencies in a certain bandwidth to be transmitted through the filter.

A number of problems exist with most types of filters performing the above functions. There is always a substantial insertion loss even at those frequencies at the centre of the band to which the filter is tuned. The passband loss is not uniform, ie. the losses are different for different frequencies within the passband range. Furthermore, it is difficult to produce filters which can easily tuned during operation.

The present invention arose in an attempt to reduce or eliminate the above problems.

According to this invention there is provided filtering apparatus for electromagnetic radiation comprising an element located within a waveguide arranged such that in use the element is superconductive and forms at least part of a resonant structure for filtering radiation propagated along the waveguide.

Superconductivity is the property exhibited by some materials when their temperature is reduced below a critical transition temperature Tc. Below this temperature, the electrical resistance of the material becomes effectively zero and the material behaves as a perfect conductor. Thus when the filter is in use and the element is in its superconductive state, the electrical resistance on its surface is effectively zero. This greatly reduces the insertion loss by reducing the power losses normally associated with the surface resistance of the element. With conventional apparatus these power losses are significant even at the centre of the passband frequency, and increase towards the edge of the passband frequency range. The use of apparatus in accordance with

the invention produces lower loss, which is more linear throughout the passband range providing a clearly defined frequency cut off outside this range which is imposed by the geometry of the resonant structure.

Preferably, the filtering apparatus comprises a plurality of elements, each forming at least part of a resonant structure for filtering radiation propagated along the waveguide. The lower power loss per element enables either a lower overall loss value for the device to be attained, or better filtering to be achieved by the use of more elements for a given overall power loss.

Advantageously, the filtering apparatus comprises at least one element which is switchable between a superconductive and non-superconductive state and, preferably, where there are several elements they are independantly switchable between their superconductive and non-superconductive states. This switching may be performed by controlling the temperature and changing it above and below the critical temperature Tc, at which the material of the element changes state, but preferably, the switching is achieved by changing the magnetic flux density at the element. When an element is in its superconductive state, if the magnetic flux density is changed above a

certain critical value Hc(T) dependant on the temperature then the element returns to its non-superconductive state. The preferred means of switching the element is by passage of an electric current through it which creates a magnetic flux density at the element greater than Hc(T). Once this current is switched off the field drops below Hc(T) and the element again becomes superconductive. This method facilitates a fast convenient switching means providing more compact apparatus than could be achieved if, for example, a coil were used to induce the field, and also permits greater design flexibility.

An advantage of apparatus in accordance with the invention is that it is possible to change the state of an element or elements within a filter after assembly or during operation enabling the filter to be switched from a superconductive to a lossy state thereby providing a built in protection device to stop the transmission of unwanted signals through the filter. This could be used for example to protect a receiver which may be damaged by high intensity signals from a nearby source.

Alternatively if at least one switchable element is a thin film element then when switched to its non-superconducting state it will have little or no effect

on the propagation of electromagnetic radiation, as the thin film will not be lossy. In this manner the filter may be reconfigured by selecting an element or elements to be either superconducting or non-conducting, and so the characteristics can be adjusted or tuned provided that the tunable range does not exceed the propagation cut-off frequency of the waveguide.

The element may be a tape cast high temperature superconductor. This is a strip of material which in its green state is in the form of flexible tape which can be stamped or cut into the desired form before being fired, whereupon it becomes rigid, prior to being assembled in the waveguide.

The invention will now be described by way of example only, with reference to the drawings, of which:

Fig 1A is a perspective view of a comb-line filter in accordance with the invention;

Fig 1B is a graph illustrating the characteristics of a conventional comb-line filter and those of the one shown in Figure 1A;

Fig 2A is a perspective view of a tape cast insert band-pass filter in accordance with the invention;

Fig 2B is a graph illustrating the characteristics of a conventional metal insert band-pass filter and those of the filter shown in Figure 2A;

Fig 3A shows a TE_{01} mode bandpass filter in accordance with the invention; and

Fig 3B is a graph illustrating the characteristics of a conventional TE_{01} mode bandpass filter and those of the filter shown in Figure 3A:

With reference to Figure 1A, a comb-line filter in accordance with the invention comprises an enclosure 1 having a first input element 2, constructed of a high temperature superconductive material, to which an input signal is applied. Standing waves generated by the first element cause excitation sequentially of three further resonant elements 3. An output signal is derived from a final element 5.

The elements 3 and 5 are all constructed of a similar material to the input element 2.

The elements 3 are in length less than one quarter of the wavelength of the desired frequency to be passed and can be tuned so as to transmit the desired frequency by adjustment of screws 4 which control the capacitance of each element 3.

In operation, the whole of the filter is cooled to below the critical temperature of the elements by immersion in a bath of liquid nitrogen (not shown).

The benefits of using elements 2,3 and 5 of a superconductive material instead of conventional material are illustrated in Figure 1B. The line A shows the performance characteristics of a conventional filter and line B shows those of the filter shown in Figure 1A. The reduction in resistive losses due to the use of a superconductive material results in a lower overall loss and a flat bandpass region 6.

Although a comb-line filter is illustrated, the same technique can be applied to similar devices where

the resonantors comprise flat metal strips on a substrate in the form of a printed circuit board. One such example is the use of the invention applied to interdigitated type filters.

An alternative band-pass filter is shown in Figure 2A and comprises a waveguide 7 formed from two sections 8A and 8B. These sections sandwich in the E-plane a tape cast high temperature superconductor 9 which before being fired to form a ceramic oxide, takes the form of a flexible flat strip into which resonant apertures 10 are cut or stamped.

Portions 11 of the superconductor 9 project into the waveguide 7, and are spaced apart by a distance approximately $\lambda/2$, where λ is the wavelength of the radiation that is transmitted by the filter. Again in operation, the filter is cooled below the critical temperature of the superconductor 9. The Figure 2B shows a comparison of the performance of a conventional metal insert bandpass filter (Line A) and an insert filter in accordance with the invention (Line B).

A third type of bandpass filter, a TE_{01} mode filter is illustrated in Figure 3A, and comprises a cylindrical waveguide 12 within which are located annular elements 13,

14, 15 and 16 of a thin film superconductive material. The elements 13 to 16 may be electrically insulated from the waveguide 12 the whole device being cooled below the critical temperature of the superconductive material being used. Each element is connected to an electrical conductor 17,18, 19 or 20. By applying a current through any element via the appropriate conductor an induced magnetic field at that element can be created which is greater than the critical field of the material. This changes the state of the element rendering it non-superconductive, in which state the element, being made of a thin film compound has little effect on radiation propagating along the guide 12.

By selectively switching the elements 13 to 16, different filtering characteristics may be selected, provided that the freqency propagated is not outside the cut-off frequency of the waveguide. Within this limitation if more elements are available, a greater number of combinations of elements may be used, giving a correspondiong increase in the choice of frequency offsets from the centre frequency.

Alternatively, if one of the elements is replaced by a thick film substrate, then by switching this element to its non-superconductive state, the element becomes lossy

and prevents transmission of radiation through the filter.

Figure 3B illustrates the advantages of a TE_{01} mode bandpass filter in accordance with the invention (the characteristics of which are illustrated by Line B) over a conventional filter of this type. (Illustrated Line A) The insertion loss is far lower giving an ultra-low-loss filter with a very narrow band-pass region.

CLAIMS

1. Filtering apparatus for electromagnetic radiation comprising an element located within a waveguide arranged such that in use the element is superconductive and forms at least part of a resonant structure for filtering radiation propagated along the waveguide.

2. Apparatus as claimed in Claim 1 and including a plurality of elements each forming at least part of a resonant structure when in a superconductive state.

3. Apparatus as claimed in claim 1 or 2 wherein the element comprises a high temperature superconductor.

4. Apparatus as claimed in Claim 1, 2 or 3 wherein the element comprises a ceramic oxide material.

5. Apparatus as claimed in any preceding claim wherein the element is a tape cast high temperature superconductor.

6. Apparatus as claimed in any preceding claim wherein at least one element is switchable between a superconductive and non-superconductive state.

7. Apparatus as claimed in Claim 6 wherein a plurality of elements are included, each element being independently switchable between a superconductive and non-superconductive state.

8. Apparatus as claimed in claim 6 or 7 wherein at least one switchable element is a thin film element.

9. Apparatus as claimed in Claim 6, 7 or 8 comprising means for switching an element between its superconductive and non-superconductive states by varying the magnetic flux density at the element.

10. Apparatus as claimed in Claim 9 wherein the magnetic flux density is varied by controlling the passage of an electric current through the element.

11. Apparatus as claimed in any of Claims 6 to 10

wherein an element is switched to modify the filtering characteristics of the apparatus.

12. Apparatus substantially as herein described with reference to any of the Figures 1A, 2A or 3A.

Published 1991 at The Patent Office, State House, 66/71 High Holborn, London WC1R 4TP. Further copies may be obtained from Sales Branch, Unit 6, Nine Mile Point, Cwmfelinfach, Cross Keys, Newport, NP1 7HZ. Printed by Multiplex techniques ltd, St Mary Cray, Kent.